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(54) **Erbia-bearing core**

(57) A ceramic core that includes, prior to core sintering, erbia filler material alone or admixed with a second ceramic filler material, such as alumina, and a binder to provide a core that is relatively non-reactive with superalloys used in the manufacture of turbine blades, dimensionally stable during directional solidification (DS) for extended times, removable by chemcial leaching techniques, and having enhanced X-ray detectable during post-cast inspection operations. After core sintering, the ceramic core has a microstructure comprising an erbia-alumina garnet phase and an unreacted ceramic filler phase (e.g. alumina).

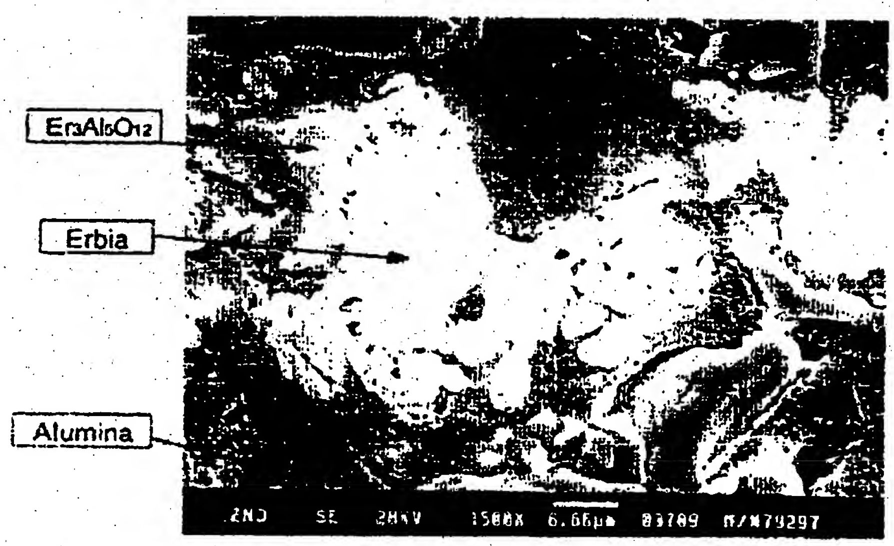

FIG. 1B

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the thermoplastic wax to provide the as-molded core with higher green strength. A suitable strengthening wax is available as Strahl & Pitsch 462-C from Strahl & Pitsch, Inc. West Babylon, New York. A suitable anti-segregation agent is an ethylene vinyl acetate coploymer such as DuPont Elvax 310 available from E.I. DuPont de Nemours Co., Wilimington, Delaware. A suitable dispersing agent is oleic acid.

[0019] An optional fugitive filler material may be present to impart a controlled porosity to the core and can comprise a carbon-bearing filler material, such as reactive grade graphite powder having a particle size of -200 mesh, available from Union Carbide Corporation, Danbury, Connecticut.

[0020] The ceramic filler powders typically are prepared by mechanically mixing together appropriate proportions of the erbia filler powder, second ceramic filler powder, and optional fugitive filler powder using conventional powder mixing techniques. A conventional V-blender can be used to this end.

[0021] Once the filler powder mixture is prepared, the mixture is blended with the binder, such as the thermoplastic wax-based binder described in detail, in appropriate proportions to form a ceramic/binder mixture for injection molding to shape. The filler powders and binder can be blended using a conventional V-blender at an appropriate elevated temperature to melt the thermoplastic wax-based binder.

[0022] A desired core shape is formed by heating the ceramic/binder mixture above the melting temperature of the binder to render the mixture fluid for injection under pressure into a molding cavity defined between suitable mating dies which, for example, may be formed of aluminum or steel. The dies define a molding cavity having the core configuration desired. Injection pressures in the range of 500 psi to 2000 psi are used to inject the fluid ceramic/binder mixture into the molding cavity. The dies may be chilled at room temperature or slightly heated depending upon the complexity of the desired core configuration. After the ceramic/binder mixture solidifies in the molding cavity, the dies are opened, and the green, unfired core is removed.

[0023] The green, unfired core then is subjected to a prebake heat treatment with the core positioned on a ceramic setter contoured to the shape of the core. The ceramic setter, which includes a top half and a bottom half between which the core is positioned, acts as a support for the core and enables it to retain its shape during subsequent processing. After the core is positioned on the bottom half of the ceramic setter, it is covered with a graphite powder packing material which serves to phsyically extract via capillary action the binder from the core in a debinding action. The time and temperature for the prebake heat treatment are dependent on the cross-sectional thickness of the core. A suitable prebake treatment may be conducted for approximately 5 hours at 550 to 600 degrees F for a maximum turbine blade airfoil core thickness of approximately 1/2 inch.

[0024] After the prebake heat treatment, the graphite packing material is brushed off the baked core and the bottom half of the ceramic setter. Then, the top half of the ceramic setter is mated with the bottom half thereof with the baked core encapsulated therebetween in preparation for sintering in ambient air to form a sintered core. Preferably, the core is sintered for approximately 1 hour using a heating rate of about 60 degrees C to about 120 degrees C per hour to a sintering temperature in the range of about 1650 to about 1670 degrees C.

[0025] Durng the sintering operation, any carbon-bearing fugitive filler powder material present is burned cleanly out of the core. As a result, an interconnected network of porosity is created in the sintered core. The porosity in the core aids in both the crushabiity and leachability of the core after casting and inhibits re-crystallization of the metal or alloy cast about the core. Thus, the sintered core preferably should include an amount of porosity sufficient to allow the core to be leached from the casting using standard hot aqueous caustic solutions in a reasonable time period. An interconnected core porosity of at least about 40 volume % and preferably in the range of 45 to 55 volume % is sufficient to this end.

[0026] During the sintering operation, the erbia filler powder material can react with second ceramic filler powder material present to form a core microstructure comprising 1) erbia-alumina garnet phase and 2) unreacted ceramic filler phase such as alumina as the major phases present. For example, the sintered core can have a microstructure comprising erbia-alumina garnet phase components when alumina is the second ceramic filler and an unreacted alumina phase component as the major phases present, see Figures 1a and 1b. Trace amounts of free, unreacted erbia and possibly $ErAlO_3$ may be present as minor phases in the sintered microstructure. The erbia-alumina garnet phase components extend throughout the sintered microstructure as a network connecting the alumina phase components to improve the high temperature stability of the microstructure.

EXAMPLES

[0027] Table I sets forth ceramic filler powder compositions for specimens ACE-1 through ACE-5 made pursuant to the present invention and also a comparison filler powder composition for specimens A devoid of an erbia filler powder. The volume percentages of the filler powder components used are shown. In specimens ACE-1 and ACE-5, erbia powder was substituted for yttria powder. Different amounts of erbia filler powder were used in specimens ACE-1 to ACE-5.

10. A sintered ceramic co at elevated temperatu

11. A sintered ceramic co phase, and a ceramic

12. The core of claim 11 v

13. The sintered ceramic

14. The sintered ceramic

15. A method of investme bearing ceramic core i ifying the molten meta

16. The method of claim 1 net phase and an unr

17. The method of claim 1 casting to X-ray radio

ne of claims 1-9 sintered

an erbia-alumina garnet

unreacted erbia.

rity of the microstructure.

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about the core, and solid-

ng an erbia-alumina gar-

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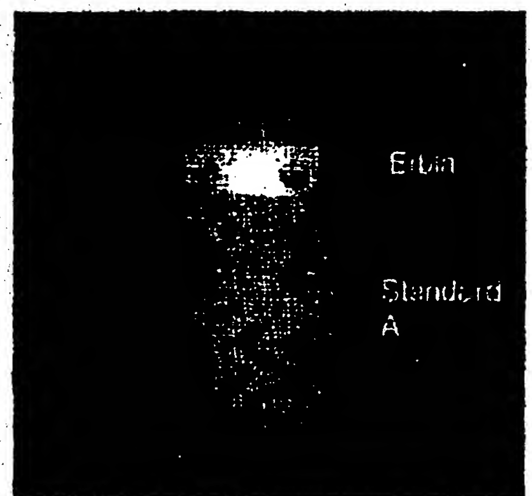
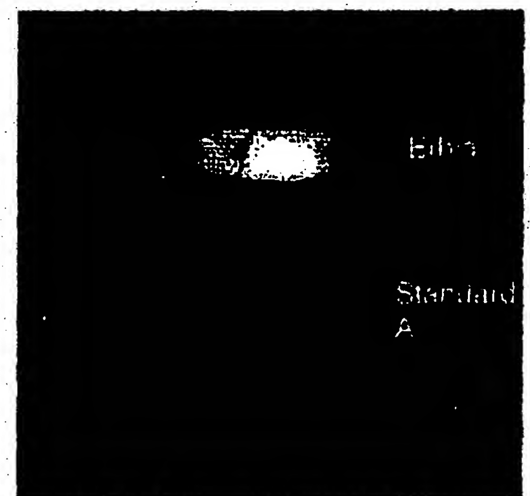


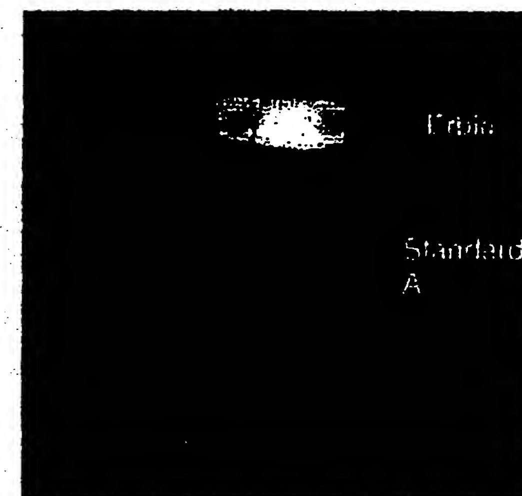
0.070" / 0.035"
Alloy Sandwich

FIG. 2A



0.070"
Alloy

FIG. 2B



0.140"
Alloy

FIG. 2C

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EUROPEAN SEARCH REPORT

Application Number
EP 98 11 9450

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DATABASE WPI Section Ch, Week 8836 Derwent Publications Ltd., London, GB; Class L02, AN 88-255084 XP002088572 ANONYMOUS: "Mfr. of wear-resistant sintered erbia-alumina ceramics - by mixing aq. solns. of polyvalent metal cation and ammonium polyacrylate, recovering ppte., burning and calcining"	1-16	B22C1/00 B22C9/10 B22D29/00
Y	* abstract * & RESEARCH DISCLOSURE, vol. 291, no. 026, 10 July 1988, Emsworth, GB	17	
D,Y	US 5 242 007 A (REMMERS TIMOTHY M ET AL) 7 September 1993 * whole document *	17	
A	US 4 040 845 A (RICHERSON DAVID W ET AL) 9 August 1977 * whole document *	1-5,7-10	
A	EP 0 722 919 A (UBE INDUSTRIES) 24 July 1996 * page 2, line 23 - line 29 * * examples 4,5 * * comparative example 2p * claims *	11-16	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

B22C
B22D
G01N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 December 1998	Riba Vilanova, M

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 11 9450

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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